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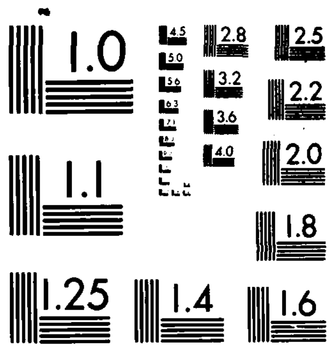

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by

Qian Yongnian

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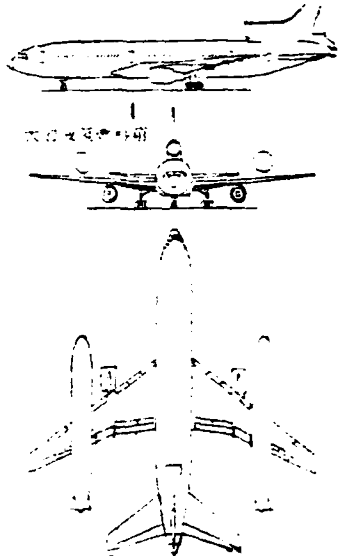
LIQUID HYDROGEN FUELED PASSENGER AIRCRAFT

Qian Yongnian

Up to the beginning of the 1980's, the world oil reserve was known to be a total of 120,000,000,000 tons. The consumption of oil in the world nevertheless is increasing by leaps and bounds. In the late 1960's, the consumption of oil was 2,000,000,000 tons. But by the late 1970's, it increased to 3,000,000,000 tons. It is estimated that by the late 1990's, the demand for oil, including the demand from chemical industries, will amount to 7,000,000,000 tons. Consequently, as the main source of energy, oil resources will be faced with the danger of exhaustion. As regards the current oil reserve and recovery, it is estimated that the oil reserve will not last for more than 30 or 40 years. The scarcity and soaring prices of petroleum have already posed a direct threat to the air transportation industry. If energy resources are not to be explored, under such circumstances there will eventually be serious problems that will impede the growth of the air transportation industry.

Nuclear energy will probably be the major low cost source of energy for mankind in the near future. However, since the source of U235 is limited and, in addition, nuclear energy produces pollution, it is not yet the most ideal source of energy. From a long term standpoint, solar radiation will eventually become the fundamental source of energy for mankind, which of course, will depend on improving the technology of direct utilization of solar energy. So far, however, it is not yet possible to apply nuclear and solar energy extensively to airplanes. The utilization of solar energy as applied to aircraft is still limited to small scale and low speed experiments.

In order to propel aircraft, space shuttles, etc., it is still necessary to utilize some liquid-state and gaseous-state fuel. Compared with each other, hydrogen is more ideal. Recently, liquid hydrogen has been generally applied to carrier rockets and space



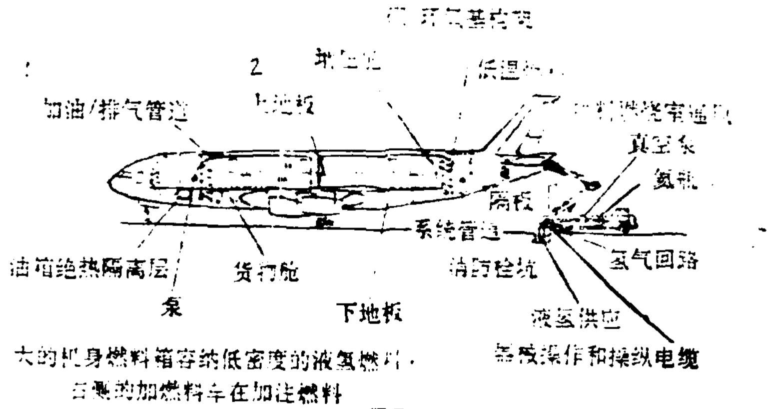
1- wing tanks
Figure 1

shuttles. The current method of extracting hydrogen, however, is still through reducing water with coal, or through hydrogenating petroleum products by splitting action, which is still a conventional way of making hydrogen. Although it is possible to obtain hydrogen through resolving water with electricity, this is limited in use since the cost of electricity is high.

Scientists are exploring a new way of extracting hydrogen through splitting water with nuclear and solar energy. With the development of science and technology, hydrogen, as a new source of energy will be extensively applied to aircraft, trains, automobiles, ships and various other means of transportation, a much brighter prospect than using coal, petroleum and natural gas.

THE ADVANTAGES OF LIQUID HYDROGEN FUEL

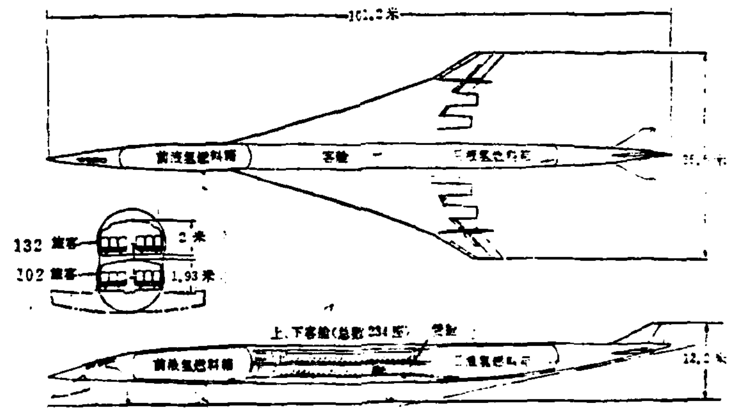
As a new type of fuel, hydrogen has many advantages. First of all, there is a big reserve of hydrogen in the Earth. Hydrogen is also in the air and water. It is inexhaustible and resourceful. Secondly, hydrogen after its exhaustion releases only water vapor or steam and instead of causing pollution, poses no danger to the human environment. This is why it is so welcomed. In addition, there is no erosive substance in liquid hydrogen fuel. In the form of steam, liquid hydrogen is sent into the engine for exhaustion which leads to the mild ignition and the proportionate spreading of temperature that help reduce the heat of metal parts, consequently extending the service life of the gas turbine by 25% and, at the same time, reducing the cost of engine maintenance. In the last analysis, many aircraft engines now in use can be easily converted for consuming hydrogen fuel.



图二

Figure 2.

1--refueling/exhaust pipes; 2--upper floor; 3--pressure increment; 4--boron/structure of epoxy resin base; 5--low-heat fuel; 6--vent for fuel exhaustion; 7--vacuum pump; 8--helium bottle 9--hydrogen return; 10--spacer; 11--structural piping; 12--fire hydrant; 13--liquid hydrogen supply; 14--instrument operation and cable control; 15--lower floor; 16--cargo cabin; 17--pump; 18--heat insulating layer of fuel tank; 19--large fuel tank containing low density liquid hydrogen fuel; 20--refueling vehicle feeds fuel on the right hand side of Figure 2



图三

Figure 3.

1--101.2M; 2--36.6M; 3--12.2M; 4--rear tank for liquid hydrogen fuel; 5--passenger cabin; 6--cargo cabin; 7--upper and lower passenger cabins (234 seats total); 8--1.93M; 9--2M; 10--102 passengers; 11--132 passengers; 12--the front tank for liquid hydrogen fuel

THE CHARACTERISTICS OF HYDROGEN FUEL AND ITS IMPACT ON THE DESIGN OF AIRCRAFT

In order to apply hydrogen fuel to aircraft, it is necessary to store hydrogen in fuel tanks in a liquid state as liquid hydrogen possesses four characteristics as follows:

1. High calorific value. Calorific value of liquid hydrogen is equivalent to three times its weight of ordinary aeronautic fuel. Given the same distance in flight, the consumption of fuel by a liquid hydrogen engine can be reduced relatively to two-thirds. Since the weight of liquid hydrogen fuel is only one-third of ordinary aeronautic fueled, it reduces the weight of liquid hydrogen powered aircraft and is helpful for the technical improvement of aircraft.

2. High specific heat. Since the temperature of liquid hydrogen fuel is low, it can be used to effectively cool the heated parts of an aircraft instead of utilizing cool air supplied from the engine cycle to serve the purpose. The cooling properties of liquid hydrogen allow engines to have higher turbine inlet temperature and a higher pressure increase. In light of these possibilities, we can make a much smaller, much lighter and much more effective kind of engine. Now that the weight and consumption of fuel are reduced, the aircraft can have a lighter wing capacity, less air resistance and higher propulsive power, etc. As far as passenger aircraft are concerned, the combination of light wing capacity and high propulsive power will lend themselves to better take-off and more noise reduction of the aircraft.

3. Low density. The disadvantage of liquid hydrogen fuel is its low density. Given the same amount, the bulk of liquid hydrogen is about four times as large as the ordinary aeronautic fuel. This causes the size of fuel tanks to be larger. As a result, the pneumatic power is impeded which, in turn, increases air resistance. No matter what measures are taken in design, it is not possible to

entirely get rid of such a problem. Improvement can be made.

4. Low temperature. The low temperature and volatility of liquid hydrogen fuel make aircraft design and aircraft refueling structure more complex. The temperature of liquid hydrogen is 235°C below 0. This requires a specially made fuel tank and the separation of the fuel tank from the fuel piping with heat insulating material. In addition, it is necessary that the pressure with the fuel tank should be adjustable so that the loss of liquid hydrogen fuel through volatization can be reduced to the minimum. While a new way of fuel feeding is necessary, there also needs to be special measures taken of ground preservation, loading and unloading of fuel

THE DESIGNING CHARACTERISTICS OF LIQUID HYDROGEN FUELED PASSENGER AIRCRAFT

The designing characteristics of liquid hydrogen fueled passenger aircraft are in the arrangement of the position of fuel tanks, fuel piping and passenger cabins.

Since liquid hydrogen fuel is dense in nature, the bulk of fuel tanks is larger and heat insulating material is necessary. It is required that the proportion of fuel tank surface area with that of fuel tank volume be kept down to the smallest possible shape, in order to cut down the loss of fuel through volatilization and to avoid having to use too much heat insulating material that causes the increase in weight. This kind of design is different from that of ordinary passenger aircraft where, as is done conventionally, fuel tanks are installed in wings.

Lockheed Company once considered installing two large size fuel tanks between two wings of an aircraft (Figure 1). This, however, was eventually given up.

The current trend in the design of liquid hydrogen fueled aircraft is toward the possibility of having fuel tanks installed

inside the body of an aircraft, instead of having them put either outside or inside the wings. As indicated in Figure 2, the installation of fuel tanks will be positioned both in the front and rear of the passenger cabin inside the body of an aircraft, with the fuel tanks wrapped up by heat insulating material. The fuel tanks will be connected by synthetically made piping structure and titanic alloy joints with the operating engine system. Such a design will help keep down heat transmission and structural weight to the minimum.

Since the temperature of liquid hydrogen is low, it is required that the insulating material for the fuel tanks (also including fuel tank trestles) have effective heat insulating ability so as to restrict the volatilization of liquid hydrogen. Because of the large area of insulation, it is necessary that the insulating material be made as light as possible. Although such light heat insulating material has been generally adopted in the field of astronautics, it is limited to the short-term use. A passenger aircraft is different because its heat insulating system, being in use for 15 to 20 years, must undergo thousands of touchdown bumps and so is easily worn from use. Therefore, under such circumstances high quality heat insulating material is in much demand for the purpose. In addition, service and maintenance must have easy access to such insulating material.

TWO KINDS OF PLANS

Supported by NASA, Lockheed Company has put forward two kinds of plans for the design of liquid hydrogen fueled aircraft.

The first plan is to design liquid hydrogen fueled subsonic jet aircraft. Such a kind of aircraft has a speed of Mach number 0.85, a flight of 10,000 km and has a capacity of 400 passengers. It has mid-size rear wings and four engines. The width between the two wings of the aircraft is 53 m, the length 66.9 m and the height 18.1 m. The aircraft is wide in width and the liquid hydrogen fuel tanks are installed both in the front and rear parts

of the aircraft, leaving the middle part of the aircraft to be the passenger cabin. The passenger cabin is 36.9 m long, divided into an upper deck and a lower deck (see Figure 2).

The second plan is to design liquid hydrogen supersonic passenger jet aircraft (see Figure 3). Such an aircraft has a speed of Mach number 2.5, a flight range of 7800 km and a capacity of 230 passengers. The total weight of the aircraft in takeoff is about 171 tons. It has long narrow triangular wings. The width between the two wings of the aircraft is 36.6 m, the length 101.2 m and height 12.2 m. The liquid hydrogen fuel tanks are installed in the front and rear parts inside the aircraft. The middle part is the two decked passenger cabin with six seats in each row. The height of the upper deck is 2 m and the height of the lower is 1.93 m.

PENDING PROBLEM

The utilization of liquid hydrogen fuel signals a new phase for the manufacturers of aircraft. The problem we are faced with now, however, is the high cost of large extraciton of liquid hydrogen. Officials from the San Francisco International Airport in the USA have made a prediction on the airport's demand for liquid hydrogen in 1995. It is necessary that a plant be set up in order to supply 900 tons of liquid hydrogen every day. The investment in such a plant has reached as much as three billion dollars. The Chicago O'Hare International Airport has an investment of about $420 millions for the same project. In addition to the high cost of liquid hydrogen extraction, there is the problem of safety, especially at airports. The liquid hydrogen is liable to cause fire when spilled during refueling. This would require a complete set of refueling equipment. Also, it is necessary to install sound pipelines that carry liquid hydrogen from the plant. All this preparation again calls for a large investment. Danger can occur to passengers if the aircraft crashes, because fire can be caused by the liquid hydrogen spilled into the passenger cabins from the broken pipings. Much research and experiments are yet to be done

to properly use liquid hydrogen fuel. It is perhaps not possible that liquid hydrogen fueled aircraft be put in use in the next 20 years. Nevertheless, because of the important value of hydrogen, the general utilization of hydrogen as fuel for aircraft will be possible sooner or later.

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